Final Summary of ICCR Source Work Group Meeting
Durham, NC
September 18, 1997
Stationary Combustion Turbine Work Group

I. Purpose

The main objectives of the meeting were to resolve the dioxin emission issue, discuss the list of HAP pollutants, discuss the status of each task group, and identify the advantages of applications of duct burners.

II. Location and Date

The meeting was organized by the US Environmental Protection Agency (EPA) and was held at the Omni Hotel, 201 Foster Street, Durham, North Carolina. The meeting took place on September 18, 1997.

III. Attendees

Meeting attendees included representatives of the OAQPS Emission Standards Division, trade associations, academic and environmental groups, and state agencies. A complete list of attendees, with their affiliations, is included as Attachment I.

IV. Summary of Meeting

The meeting consisted of discussions and presentations between WG members and public participants on selected issues which are listed below. The meeting also included presentations conducted by duct burner manufacturers. The order of the meeting followed the agenda provided as Attachment II. A bullet point summary of the meeting is presented as Attachment III.

The topics of discussion included the following:

- Discussion of the outcome of the CC meeting
- Test Methods, Monitoring, and Testing Task Group status
- Database Enhancement Task Group status
- Subcategorization Task Group status
- HAP Reduction Task Group status
- HAPs vs. Criteria Task Group status
- Discussion of risk assessment studies
- Discussion of pollution prevention options applicable to turbines
- MACT Floor Screening Task Group status
- Presentation of Duct Burners
- Planning Task Group status
- Next Meeting

Discussion of the Outcome of the CC Meeting

The WG reviewed the decisions of the CC meeting and discussed items which need to be developed in response to the CC decisions. S. Roy suggested developing a schedule of topics and target dates for completion to report to the Tracking Committee of the CC by the next meeting. S. Roy and M. Schorr will draft a proposed schedule of such topics and circulate it to the WG.

S. Roy reminded WG members to keep pollution prevention measures in mind. EPA will provide examples for the WG to examine for ideas. S. Roy pointed out that since the WG is dealing with historical data, there is not a logical way to infuse this information at this time. He remarked that the appropriate time to incorporate pollution prevention would be at the time of regulation development.

Other CC meeting suggestions that might affect the CTWG include considering dioxin as a pollutant for which to test and factoring in environmental justice during deliberations. It was also pointed out that the WG needs to identify which issues are necessary to be taken to the CC for concurrence and which issues can be reported to the CC as decisions.

Test Methods, Monitoring, and Testing Task Group

S. Roy presented to the WG the recommended list of pollutants to be measured, categorized by fuel type. This presentation is included as Attachment IV. It was suggested that the list of pollutants for each fuel type include, at a minimum, the list of pollutants identified for natural gas. (Any other pollutant specific to the tested fuel (such as beryllium and cadmium compounds for diesel fuel) should also be tested for that fuel-fired turbine). Concerns were raised about detection limits and about the inclusion of pollutants in the HAP list that were reported below the detection limit. S. Roy commented that proper justification is needed to take metallic HAPs off of the lists. Consensus was reached on not including dioxin on the HAP lists for diesel, natural gas, and digester gas fired turbines. S. Gieryn will look into justification for including dioxin for turbines firing other fuels, such as landfill gas. S. Roy suggested that a surrogate might be found for a group of pollutants when setting regulations, to avoid setting individual regulations for each tested pollutant. J. Klein pointed out that there do not seem to be any suitable surrogates for HAPs. The subgroup was asked to reach consensus on the pollutant list issue before the next meeting.

Concerns were raised about the quality of the source test reports. T. Harrison looked at the methods used in the reports and reported that he could not invalidate them. He did not, however, review the actual reports. C. Solt and M. Schorr both found instances of data reported below the detection limit in the source test reports which they reviewed. C. Solt, M. Schorr, S. Roy, and G.

Brown will revise the HAPs lists after reviewing the database. The new lists will be sent out to the WG, with the possibility of a teleconference to discuss them.

Other topics discussed by the Testing Task Group included identifying technical rationale for excluding pollutants which are detected at levels close to the detection limits. B. Lott identified a document which discusses limits close to the detection limits. B. Lott indicated that as the level of science increases, the detection limits decrease, yielding additional detected pollutants with negligible emission levels. This will increase the costs of testing for no significant reason. He concluded that if the measured pollutant levels are extremely low, it is highly possible that the pollutant does not exist, and that the WG should not spend the additional expense to verify this issue. S. Roy reported that he had discussed this issue with the TMPWG. T. Harrison and F. Mohammed indicated that if a pollutant is detected at detection level, then the pollutant is very likely to be there. In an effort to resolve this issue, J. Preczewski was asked to check with the Testing and Monitoring Protocol Work Group about detection limits for HAPs and how other groups are treating metallic HAP emissions.

G. Adams suggested developing a uniform list of pollutants across the source categories to the degree that the combustor specifics allow, in an effort to minimize the efforts of the ICCR.

C. Solt suggested that since metals are related to surface corrosion, it could be feasible for turbine manufacturers to measure two units, one old and one new, to determine a wear or corrosion rate for estimating chromium or metals emissions. M. Schorr and M. Long indicated that such small weight differences would be hard to detect because of the enormous size of these units.

Database Enhancement Task Group Status

B. Richani presented to the WG the Refinement Activities of the Population Database. This presentation is attached as Attachment V.

G. Adams requested that Alpha-Gamma provide the capacity conversion calculations to WG members for review.

Many concerns were raised about merging the 1992 data with the ICCR database. C. Solt recommended keeping it as a separate table in the ICCR database. M. Schorr expressed concern about duplication of units if the 1992 data were merged, citing an example of a General Electric plant that was associated with six different names.

Many WG members commented on the adequacy of the database. G. Adams reported that the responses that he received from Columbia Gas and Tennessee Gas indicated that the population data in the ICCR Population Database did not have substantial problems; some units were simply overlooked. J. Klein registered his concern that he has only seen a small fraction of Arco's turbines in Alaska in the ICCR database. The WG requested that Alpha-Gamma provide size distributions of the turbines in the database. There was general agreement that the database can be used for population and model plant representation.

Subcategorization Task Group Status

There is no new information regarding potential subcategories. The Task Group will review the subcategories identified through previous EPA efforts, including the 1992 Section 114 work.

HAP Reduction Task Group Status

No new information was presented. J. Klein mentioned that he has not received any more information on carbon monoxide as a surrogate for HAPs.

HAPs vs. Criteria Task Group Status

Prior to the WG meeting, C. Chang distributed to the task group members documents that have been collected on the subject of HAPs vs. Criteria pollutants. He requested that the task group members complete review of the distributed documents and be prepared to discuss their comments in a teleconference in late October.

Risk Assessment Studies

One of the action items from the last meeting was that S. Roy would report to the WG on the procedures and requirements for delisting a source category and/or subcategory as a result of previously discussed risk assessment studies. S. Roy indicated that delisting requires a significant effort and that EPA management will not approve delisting unless no other alternatives exist. G. Adams expressed his interest in the potential subcategory of digester gas fired turbines being delisted since he represents the only combustion turbine facility firing digester gas in the United States. D. McConkey was asked to look into delisting of a subcategory and provide comments to the WG.

G. Adams questioned how risk assessment studies will be used. It was recommended that they be used for prioritization of WG tasks, but not for delisting sources. S. Roy, C. Solt, and B. Richani will identify pollutants and their corresponding concentrations to be used in a risk assessment study for turbines by the next WG meeting.

Discussion of Pollution Prevention Options Applicable to Turbines

It was determined that the WG request examples of pollution prevention form EPA. S. Roy will report back to the WG on this issue.

MACT Floor Screening Task Group

The MACT Floor Screening Task Group attempted to get information from the emissions and population databases. S. Roy indicated that there may be a six to nine month delay before all of the emissions data are obtained. He also indicated that the Task Group decided to proceed with identifying potential MACT Floors and not to wait until all tests have been gathered. The Task Group had planned to have preliminary information regarding MACT floor by the November meeting; however, subsequent to further discussions, it was decided to postpone this task until the February meeting.

The Task Group has had two teleconferences since the last CTWG meeting and has initiated screening procedures. When intermediate steps are reached, they will be summarized and reported back to the WG. The Task Group will look at the emissions data in the ICCR Emission database to determine if the data are adequate or if the Task Group needs to look elsewhere for information.

PRESENTATIONS: Duct Burners

Three presentations were given on duct burners from representatives from duct burner manufacturers: J. Conroy of Forney Corporation, R. Waibel of Koch Engineering Company, and S. Drennan of Coen Company, Inc. These presentations are included as Attachment VI. A main conclusion of the presentations is that no data currently exist on control efficiencies of duct burners for HAP emissions. This is an area of research which duct burner manufacturers plan to investigate soon. Theoretically, duct burners will incinerate some HAPs contained in all fuels. One presenter postulated that potentially, a duct burner could help mitigate HAP problems from turbines. Duct burners are used for natural gas, #6 fuel oil, and #2 fuel oil.

The WG questioned whether duct burners should be included in CTWG considerations or if they should be considered solely by the Boiler WG; however, no consensus was reached.

Planning Task Group

The Task Group discussed model plants and parameters. S. Roy suggested looking at the 1993 Turbines ACT for developing model plants, parameters and protocols for testing. A new task group was formed, led by S. Roy. The new task group will try to use the expertise of the WG to ascertain how the model plant concept can best be developed using the expertise within the Work Group. The Task Group will look at different sized plants, cost information, and typical scenarios by SIC Code. An attempt will be made to develop model plants by industry; e.g., pipeline, electric, chemical, etc. S. Roy will draft a document on the concept of developing and using model plants and circulate it to the Model Plant Task Group for review.

Next Meeting

The next WG meeting will be a teleconference on October 29, 1997, from 1 to 3 p.m. EST. The potential agenda items will include a review of the revised list of pollutants for which to test, a status report from the MACT Floor Screening Task Group, status of the emissions and inventory databases, and a discussion of the schedule and timeline to be reported to the CC.

The meeting adjourned at 4:30 pm.

These minutes represent an accurate description of matters discussed and conclusions reached and include a copy of all reports received, issued, or approved at the September 18, 1997 meeting of the Stationary Combustion Turbine Work Group.

Sims Roy

ATTACHMENT I

LIST OF ATTENDEES

Stationary Combustion Turbine Work Group Meeting
September 18, 1997
List of Attendees

Sims Roy	EPA OAQPS Emissions Standards Division
Greg Adams	Los Angeles County Sanitation District
Sam Allen	Dow Chemical Company
Gordon Brown	Exxon Chemical Company
A. J. Cherian	Pacific Gas Transmission Company
Derek Furstenwerth	Houston Lighting and Power Company
Sam Gieryn	Wisconsin’s Environmental Decade
Ted Guth	Permitting Regulatory Affairs Consultant
Peter Hill	US Naval Facilities Engineering Svc. Center
John Klein	ARCO Alaska, Inc.
Diane McConkey	EPA OMB
Raimund Muller	Siemens Power Corporation
Michelle Long	Solar Turbines
Valerie Overton	Eastern Research Group
Marvin Schorr	Power Systems Engineering Department
Jeff Willis	Rolls Royce
Stan Coerr	Coerr Environmental
Bob Lott	Gas Research Institute
Brahim Richani	Alpha-Gamma Technologies
Keri Leach	Alpha-Gamma Technologies
Chuck Solt	Catalytica
John Conroy	Forney Corporation
John Preczewski	New Jersey Dept. Of Environmental Protection
Atly Brasher	Louisiana Department of Environmental Quality
Scott Drennan	COEN Company, Inc.

Richard Waibel Koch Engineering Company, Inc.

ATTACHMENT II

MEETING AGENDA

Agenda
Stationary Combustion Turbine Work Group
September 18, 1997 WG Meeting, RTP, NC

8:00 - 8:15	Welcome (S. Roy)
8:15 - 8:45	Outcome of the CC Meeting, Including the Dioxin Primer as it Applies to Turbines (S. Roy)
8:45 - 10:00	Test Methods, Monitoring, and Testing Task Group (S. Roy, T. Guth) - Status - List of Pollutants to test for Each Fuel Type - Review the pollutant lists compiled by various methods - Discussion of the analysis used by the TMPWG and other organization for pollutants measured at levels close to the detection limit - Compilation of a comprehensive list of pollutants - Discussion of the testing protocol (i.e., methods, parameters, and procedures necessary for turbine source testing)
10:00 - 10:15	BREAK
10:15 - 11:00	Database Enhancement Task Group (G. Adams, B. Richani, S. Roy) Population Information: - Status of gathering and verification of information - Status of gathering Make and Model information - Status of refining the population database - 1992 Data Emissions Data: - Status of compiling information for source test reports identified as incomplete reports - Efforts for gathering additional HAP source test reports
11:00 - 11:20	Subcategories Task Group (M. Schorr) - Status
11:20 - 11:40	HAP Reduction Task Group (J. Klein) - Status - Discussion of CO as a potential surrogate for HAPs
11:40 - 12:00	HAP vs. Criteria Task Group (C. Chang) - Status
12:00 - 1:10	LUNCH
1:10 - 1:30	Risk Assessment Studies (S. Roy and C. Solt) - Summary/status/discussions
1:30 - 2:00	Discussion of Pollution Prevention Options Applicable to Turbines - Status
2:00 - 2:20	MACT Floor Screening Task Group - Status
2:20 - 2:30	BREAK
2:30 - 4:30	PRESENTATIONS - Duct Burners

4:30 - 4:45	BREAK
4:45 - 5:15	Planning Task Group (S. Roy, M. Schorr) - WG status - Future activities/next steps (developing model plants and parameters)
5:15 - 5:30	Compose the meeting flash minutes and develop agenda items and schedule for the next work group meeting
5:30	ADJOURN

ATTACHMENT III

BULLET POINT SUMMARY

Summary of ICCR Source Work Group Meeting
Combustion Turbines Work Group Meeting
Omni Hotel, Durham, NC - September 18, 1997

Decisions

- Consensus was reached on revising the HAP pollutant list to include only those pollutants that are detected above the detection limits.
- A Model Plant Task Group was formed, headed by S. Roy. Its members include G. Brown, A.J Cherian, and possibly S. Allen.
- Consensus was reached on not including dioxin on the HAP lists for diesel and natural gas turbines.
- The WG will factor in Pollution Prevention and Environmental Justice issues during deliberation.

Next Meeting

- The next Combustion Turbine Work Group Meeting will be a teleconference on October 29, 1997, from 1:00 - 3:00 pm, EST.
- Items to be discussed at the mext meeting may include:
    - The revised HAP list
    - Inventory and emissions databases
    - Status of the MACT Floor Screening Task Group
    - Schedules and timeline to be reported to the CC

Action Items

- S. Roy will request that Fred Porter put on CC agenda a discussion of which decisions workgroups must bring forward to the CC for consensus.
- Alpha-Gamma will prepare a size distribution of the turbines referenced in the ICCR CT Population Database.
- M. Schorr, C. Solt, S. Roy, and G. Brown will draft the revised HAP list.
- Alpha-Gamma will e-mail a list of turbine Makes & Models included in the ICCR CT Population Database which do not have operating parameters to WG members for their input.
- S. Roy and M. Schorr will draft a timeline for WG review by September 30.
- Alpha-Gamma will provide capacity conversion calculations for WG review by September 30.
- M. Schorr will review the 1992 Documents for potential subcategorization.
- HAP vs. Criteria Task Group will respond with comments to documents sent by C. Chang by October 31.
- J. Preczewski will request from the Testing and Monitoring Protocol Work Group (TMPWG) information about detection limits, PQL policies, and how other work groups are treating metallic HAP emissions.
- S. Gieryn will look into possible justification for testing for dioxin for turbines firing landfill gas.
- C. Solt, S. Roy, and B. Richani will meet to review risk assessment information and protocols.
- S. Roy and D. McConkey will investigate the delisting of a subcategory of turbines.
- S. Roy will put together examples of pollution prevention (based on EPA’s Pollution Prevention group) to illustrate how far the WG can/should carry the concept.
- S. Roy will draft a document on the concept of developing and using model plants and circulate it for WG review.

ATTACHMENT IV

LIST OF POLLUTANTS

CT Testing and Monitoring Task Group

List of Pollutants

September 18, 1997

Testing and Monitoring Task Group List of Pollutants

¨ Criteria:

- List of pollutants will include, as a minimum, ALL pollutants for natural gas-fired turbines regardless of fuel;
- Metallic compounds/HAPs may be removed from the list, if sufficient rational (including references to any relevant documents) is provided;
- Fuel analysis will include the metallic HAPs identified on the corresponding pollutant list; and
- Criteria pollutants will be measured simultaneously with HAP pollutants. The criteria pollutants include carbon monoxide CO, nitrogen oxide (NOx), total hydrocarbons (THC), and particulate matter (PM).

Testing and Monitoring Task Group
List of Pollutants

¨ Natural Gas:

- The list of HAPs for natural gas-fired turbines include all HAPs which were detected (in the gathered emission test reports) at levels higher than the corresponding test method detection limit. In addition, the list includes pollutants which are identified by other sources, such as, the ICCR TMPWG and EPRI.

Acetaldehyde	*Acrolein*	*Arsenic Compounds**
Benzene	*Biphenyl*	*Chromium Compounds**
Ethylbenzene	*Formaldehyde*	*Hexane*
*Lead**	*Manganese**	*Mercury Compounds**
Methanol	*Naphthalene*	*Nickel**
PAH	*Phenol*	*Styrene*
Toluene	*Xylene (o, m, & p)*	

**Metallic HAPs*

Testing and Monitoring Task Group
List of Pollutants

- #2 Fuel Oil:
  - The list of HAPs include the pollutants identified under natural gas-fired turbines and the following:

    *Beryllium Compounds**

    *Cadmium Compounds**

**Metallic HAPs*

Testing and Monitoring Task Group List of Pollutants

- Refinery Gas:
  - The list of HAPs include the pollutants identified under natural gas-fired turbines and the following:

    *Cadmium Compounds**

**Metallic HAPs*

Testing and Monitoring Task Group List of Pollutants

- Field Gas/Landfill Gas/Digester Gas:
  - The list of HAPs include the pollutants identified under natural gas-fired turbines and any additional HAP specific to the gas in question or measured under the gas in question with levels higher than the corresponding test method detection limit.

Testing and Monitoring Task Group
List of Test Methods

- Method 18 / TO-14
  - Benzene, Toluene, Ethylbenzene, Xylenes, Hexane, Styrene
- FTIR
  - Formaldehyde, Acetaldehyde, Acrolein, NOx, CO
- CARB 429 and 429(m)
  - Biphenyl, Naphthalene, PAH, Phenol
- Method 25A
  - THC
- Method 5
  - PM
- Fuel Testing for Metals

ATTACHMENT V

DATABASE REFINEMENT ACTIVITIES

Database Enhancement Task Group

Population Database - Refinement Activities

September 18, 1997

CT Population Database Refinement Activities - Status

- Gathering Make and Model Information
  - GE and Solar submitted their M&M information
  - Gathered M&M information from 1992 Data
  - Compiled an updated list of M&Ms with no operating parameters
  - List will be e-mailed to WG members. Would like feedback by September 30, 1997

CT Population Database

Refinement Activities - Status

- Capacity Information
  - Requested feedback from CTWG members regarding the assumed thermal efficiencies on Sep 15, 1997
  - Coded all necessary conversion calculations based on the SCC Code and fuel type
  - Converted all reported capacities to MW

CT Population Database

Refinement Activities - Status

- Identified Missing Records
  - Information previously submitted by the State of Tennessee did not include turbines
  - Roughly 20 units
  - Missing records will be included in Version 3

CT Population Database

- Results:
  - Total Number of turbines: 5,331

CT Population Database

Refinement Activities - Status

- 1992 Data - Background
  - The 1992 Section 114 questionnaire results have been examined to determine if they contain additional information to contribute to the current ICCR population database for turbines

CT Population Database Refinement Activities - Status

- 1992 Data Comparison:
  - Total number of turbines:

    1992: 4,051 turbines

    ICCR: 5,331 turbines
  - For 21 states, the 1992 database had more turbines than the ICCR population database
  - A manual state-by-state comparison between the 1992 Data and the ICCR Population Database was conducted to capture the additional records

CT Population Database

Refinement Activities - Status

¨ Data Limitations: Complexities Encountered

- 1. Multiple Records
- 2. Unknown Matches
- 3. Unmatched Records

CT Population Database Refinement Activities - Status

- Data Limitations - Complexities Encountered:
  - "Multiple Records": The 1992 database has more turbines for a given facility than does the ICCR Turbine Version 2 database. In this case, only the number of turbines missing can be determined, not the actual turbines

CT Population Database
Refinement Activities - Status

Example:

1992 Database:

Buyers & Site	City	State	#
COMMONWEALTH EDISON CO	LOMBARD GT 311	IL	1
COMMONWEALTH EDISON CO	LOMBARD GT 321	IL	1
COMMONWEALTH EDISON CO	LOMBARD GT 322	IL	1
COMMONWEALTH EDISON CO	LOMBARD GT 332	IL	1
COMMONWEALTH EDISON CO	LOMBARD GT 312	IL	1
COMMONWEALTH EDISON CO	LOMBARD GT 331	IL	1
		Total:	6

ICCR Turbine Database V2:

ICCR Facility ID	Plant Name	City	State	#
170430278	COM ED - GLENBARD/LOMBARD FACILITY	LOMBARD	IL	4
			Total:	4

CT Population Database
Refinement Activities - Status

- Options:
  1. Replace ICCR data with 1992 data
  2. Add to ICCR the difference between the two databases
  3. Consider the ICCR database up to date
- Findings:
  - Total number of <u>additional</u> units identified: 71 turbines
- Decisions: Add no records

CT Population Database
Refinement Activities - Status

- Data Limitations (Cont.):
  - "Unknown Match": The site location and the number of units for the same facility does not match

CT Population Database

Refinement Activities - Status

- **EXAMPLE:**
- **1992 Database:**

Buyers & Site	City	State	#
Great Lakes Gas Trans. Co.	Detroit	MI	2
Great Lakes Gas Trans. Co.	Detroit	MI	4
Great Lakes Gas Trans. Co.	Detroit	MI	3
Great Lakes Gas Trans. Co.	Detroit	MI	6
Great Lakes Gas Trans. Co.	Detroit	MI	4
Great Lakes Gas Trans. Co.	Detroit	MI	1
Great Lakes Gas Trans. Co.	Detroit	MI	1
Great Lakes Gas Trans. Co.	Detroit	MI	1
Great Lakes Gas Trans. Co.	Detroit	MI	13
Great Lakes Gas Trans. Co.	Detroit	MI	4
Great Lakes Gas Trans. Co.	Detroit	MI	4
Great Lakes Gas Trans. Co.	Detroit	MI	1
Great Lakes Gas Trans. Co.	Detroit	MI	1
Great Lakes Gas Trans. Co.	Detroit	MI	3
Great Lakes Gas Trans. Co.	Detroit	MI	2
		Total:	50

ICCR Turbine Database V2:

ICCR Facility ID	Plant Name	City	State	#
260298573	GREAT LAKES GAS TRANMISSION CO		MI	3
260532168	GREAT LAKES GAS TRANSMISSION		MI	2
260710022	GREAT LAKES GAS TRANSMISSION	CRYSTAL FALLS	MI	5
260410062	GREAT LAKES GAS TRANSMISSION	RAPID RIVER	MI	1
260530028	GREAT LAKES GAS TRANSMISSION	WAKEFIELD	MI	2
260970027	GREAT LAKES GAS TRANSMISSION LTD	NAUBINWAY	MI	2
260490486	GREAT LAKES GAS TRANSMISSION LTD	OTISVILLE	MI	3
			Total:	18

CT Population Database Refinement Activities - Status

- Options:
  1. Replace ICCR data with 1992
  2. Add <u>all</u> of 1992 to ICCR: 771 turbines
  3. Add none of 1992 to ICCR

- Decision:
  - "Brute Force Method" : AG will try to call a few of these places and see what the deal is

CT Population Database Refinement Activities - Status

- Data Limitations (Cont.):
  - "Unmatched Records": Records that seem clearly not to match between the two databases (2,208 turbines)
- Options:
  1. Keep as a separate table within the ICCR database
  2. Assign ICCR Facility ID #'s and source codes and merge with the database
- Decision:
  - Merge the "Unmatched Records" to the ICCR Population Database (Caution: May include duplication)

Attachment VI - A

Duct Burners Presentations

Presentation No. 1: Forney Corporation

(OUTLINE ONLY - For a hard copy (outline plus diagrams) of the presentation, please contact Mr. John Conroy at 972/458-6218)

Forney Duct Burners
Designs, Operations, & Emissions
By John H. Conroy, P.E.
Forney Duct Burners

Agenda
Duct Burner Design Parameters
Turbine Exhaust Firing Design Variables
Burner Emissions
Turbine Operating Modes Affecting Emissions

Forney Duct Burners
Duct Burner Design Constraints
OBJECTIVES:
Even heat distribution at boiler screen tubes
Minimize emissions added by the burner
Modulate steam flow

Forney Duct Burners
Duct Burner Design Parameters
Inlet temperature of TEG (800°F to 1100°F)
Firing Temperature (1100°F to 2200°F)
TEG Composition
Oxygen (13% to 15% by volume, wet)
Water Vapor (5% to 7% by volume)
Velocity across the burner elements
Fuel/Oxygen mixing rate
Flame Length
Flame Stabilizer Geometry

Forney Duct Burners
Typical Natural Gas Fired Straight Element

Forney Duct Burners
Typical Vertical Natural Gas Fired Arrangement

Forney Duct Burners
Typical Branched Natural Gas Fired

Forney Duct Burners
Most Common TEG Process Conditions Affecting Duct Burner Emissions
Ambient Swings
Turbine Mass Flow Rate increases with decreasing temperature
Turbine exhaust temperature decreases with decreasing temperature
Turbine exhaust oxygen content increases with decreasing temperature
Turbine exhaust water vapor content decreases with decreasing temperature

Forney Duct Burners
Most Common TEG Process Conditions Affecting Duct Burner Emissions
Turbine Load Swings
Turbine Mass Flow Rate decreases with decreasing load
Turbine exhaust temperature decreases with decreasing load
Turbine exhaust oxygen content increases with decreasing load
Turbine exhaust water vapor content decreases with decreasing load

Forney Duct Burners
Most Common TEG Process Conditions Affecting Duct Burner Emissions
Steam Injection - Power Augmentation
Turbine Mass Flow Rate increases
Turbine exhaust temperature
Turbine exhaust oxygen content decreases
Turbine exhaust water vapor content increases
Effect On Duct Burner Emissions
NOx - Decreases
CO, VOC, UBHC - Increases

Forney Duct Burners
Typical NOx Emissions

Forney Duct Burners
Typical CO Emissions

Forney Duct Burners
Emissions Control Strategies
Element Staging
Increase the local temperature, reduces CO, VOC, UBHC’s
Inexpensive cost relative to other control methods
Drawbacks
Uneven heat distribution at the boiler tube bank
Increased burner management complexity

Forney Duct Burners
Emissions Control Strategies
Air Augmentation
Increasing the local oxygen concentration at the base of the flame reduces CO, VOC, UBHC’s
Drawbacks
High initial operating cost
High capital expenses, seal air fans, start-up purge system is required
Increased burner management complexity -operation must be interlocked with the boiler purge
NOx emissions increase due to higher oxygen level

Forney Duct Burners
Emissions Control Strategies
HAP Destruction

Theoretically the duct burner will incinerate some HAP’s contained in the flue gas
Little or no data is currently available on these pollutants

Attachment VI - B

Duct Burners Presentations

Presentation No. 2:Koch Engineering Company Inc

(Presentation extracted from the attached paper - The attached paper is missing certain diagrams due to electronic formatting conversion errors. For a complete copy of the full document, please contact Mr. Richard Waibel at 918/234-5744)

Retrofitting Duct Burners for CO Control

Richard T. Waibel and Steve Somers
John Zink Company, Tulsa, OK

American Flame Research Committee International Symposium
Sept. 30-Oct. 2, 1996, Baltimore, MD

ABSTRACT

Duct burners are often installed in gas turbine cogeneration or combined cycle systems to add supplementary heat to the turbine exhaust gas (TEG) stream upstream of the heat recovery steam generator (HRSG). The turbine exhaust gas usually contains enough oxygen to sustain combustion and the duct burner is designed to use the TEG as combustion air. Although duct burners produce relatively low NOx levels due to the low oxygen content of the TEG, the levels of CO and VOC's can be greatly influenced by the composition, temperature, velocity and turbulence of the TEG stream.

In some applications, steam is added to the TEG to reduce NOx emissions produced by the turbine or to augment the power produced by the turbine. This steam further depresses the oxygen content of the TEG and can lead to increases in combustible emissions from the duct burners. An improved, low emission duct burner design has been developed to significantly minimize the effect of steam addition, turbulence and TEG velocity on combustible emissions. Data are shown for a gas turbine application that has been retrofitted with the improved design.

INTRODUCTION

Many gas turbine/heat recovery steam generator systems used in cogeneration or combined cycle applications utilize duct burners to add supplementary heat to the turbine exhaust gas (TEG) prior to the TEG entering the heat recovery steam generator (HRSG). In general the oxygen content in the turbine exhaust gas is sufficient for combustion and duct burners are designed to use TEG as combustion air. While the composition of the TEG depends on the turbine and the specifics of the application, a typical composition will fall within the range of 11 to 15% oxygen on a volume percent, wet basis. Typical TEG temperatures fall within the range of 850^{o}F to 1100^{o}F. The duct burner is generally located in the expansion duct between the turbine outlet and the heat recovery steam generator inlet. The expansion section is needed to provide the proper TEG velocity through the steam generator. Figure 1 shows a schematic diagram of a typical turbine/heat recovery steam generator system with duct burners.

The duct burner is designed to distribute the heat as uniformly as possible in the TEG stream using a series of linear runners extending across the duct at several elevations. The TEG velocity at the plane of the duct burners is normally in the range of 30 to 60 feet per second, although lower and higher velocities are occasionally encountered.

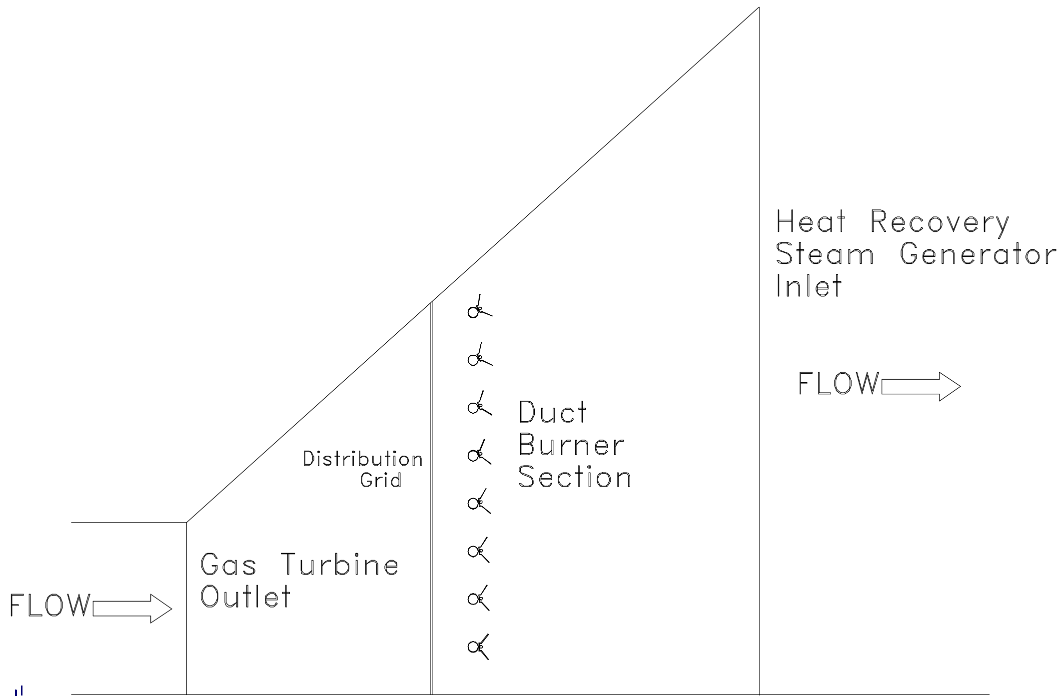


Figure 1 Schematic Side Elevation View of Expansion Duct with Duct Burners

Unfortunately the gases exiting the turbine are also highly turbulent and poorly distributed in the outlet. This turbulence and maldistribution of the flow at the turbine outlet combined with the rapid expansion of the duct cross section between the turbine outlet and the HRSG inlet leads to a gross maldistribution of the flow in the expansion duct. A typical application includes a flow distribution grid in order to improve the flow distribution. However, the flow entering the plane of the duct burners is still far from perfect. Figure 2 shows an example of a TEG flow distribution with and without a flow distribution grid. Without any flow distribution device there are significant differences in the flow (averaged across the width of the duct) at each elevation in the duct. The grid improves the flow distribution to a minimally acceptable level. Further improvement would require additional pressure drop or additional real estate. Both of these are at a premium in a typical installation.

DUCT BURNER OPERATION

A duct burner is unique in that the flow of “combustion air” is well in excess of the stoichiometric requirements and totally independent of the operation of the burner. The TEG flow rate is relatively constant and varies primarily in oxygen content as the turbine operation varies, although duct burners are normally only used when the turbine is at base load. The duct burner, therefore, is primarily a fuel injection system and the burner must be designed to mix a varying amount of fuel with a relatively constant flow of oxidant.

(Figure not included)

Figure 2 Comparison of Average Flow at Different Elevations in Duct With and

Without Flow Distribution Devices

The primary concern in duct burner design is to provide for stable ignition over a wide turndown range, normally 10 to 1, and to prevent quenching of the flame over this range of operation. Quenching can occur if too much TEG mixes with the flame prior to completion of combustion. However, rapid mixing between the combustion products and the remaining TEG flow is desirable, since a uniform temperature is required at the entrance to the HRSG. The burner design must, therefore, promote enough mixing to minimize flame length and provide a uniform temperature profile, while precluding quenching of the flame.

Figure 3 shows a schematic diagram of a John Zink duct burner. The flame holder provides a zone for ignition and flame stabilization and is perforated to allow a metered amount of TEG into the base of the flame. The flame holder shape also provides for a mixing zone downstream of the burner for completion of combustion and for mixing of the combustion products and the remainder of the TEG.

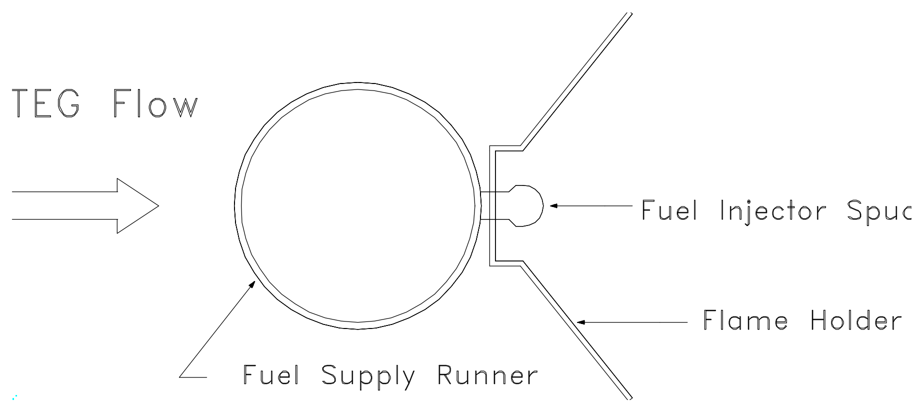


Figure 3 Schematic Cross-Section of Gas Fired Duct Burner [John Zink LDR-LE]

Turbulence and maldistribution of TEG flow complicate the design problem. Maldistribution can be in the form of variations in the velocity and mass flow at different points in the duct cross section as well as variations of the flow vector at different points in the duct. Mass flow maldistribution can lead to long flames in zones with low mass flow and velocity and quenching of the flame in zones with high mass flow and velocity. Mass flow maldistribution can also lead to excessive temperature variations at the entrance to the HRSG with high temperatures in the zones with low TEG flow and low temperatures in those zones with high flow. In some cases the fuel injection pattern has been modified to match the TEG flow distribution in order to provide a more uniform temperature profile at the HRSG entrance.

It is also desirable to have uniform flow vectors across the duct with the TEG flow parallel to the axis of the fuel injector spuds. If the TEG flow approaches the burner at an oblique angle, the fuel/TEG mixing pattern on one side of the burner will be much more rapid than desired leading to quenching of the combustion reactions. On the other side of the burner the fuel and TEG will mix much more slowly than desired leading to poor combustion and consequently combustible emissions.

Some TEG flows exhibit such large scale turbulence that the turbulent fluctuations actually cause intermittent flow reversals at the duct burner. These are seen as highly unsteady flames with the flame occasionally moving upstream behind the flame holder. This also leads to poor combustion, quenching of the flames, elevated combustible emissions and damage to the burner elements and duct casing.

RETROFIT APPLICATION

In one recent application extremely large turbulence levels were seen including intermittent flame reversals and detachment of the flame from the flame holders. The CO emissions were higher than expected both with and without steam injected into the turbine. Figure 4 shows the CO emissions versus duct burner firing rate with and without steam injection. The unit was fitted with a flow distribution device and a review of the flow modeling data showed that time averaged flow distribution was acceptable. However, the model also showed the turbulence that was found in the field and the instantaneous flow variations across the plane of the duct burners were highly non-uniform.

(Figure not included)

Figure 4 CO Emissions Versus Firing Rate with and without Steam Injection

In this case the duct from the turbine outlet expanded at a 50 degree angle up to the plane of the duct burners and expanded at 30 degrees downstream of the duct burners. Based on the behavior of the flames it did not appear that the TEG flow vectors were normal to the axis of the individual burner elements. As a first attempt to overcome the problem the individual burner runners were rotated to try to ensure that the local TEG flow was parallel to the axis of each runner. This improved the operation. However the combustible emissions were still higher than acceptable.

In order to further investigate the problem a four foot section of a full scale runner was installed in the JZ duct burner test facility. This facility can provide simulated TEG with the proper composition, temperature and velocity. Turbulence generators were installed upstream of the test section to recreate the problem seen in the field. With sufficient additional turbulence, elevated CO emissions were observed in the test facility, similar to those seen in the commercial application. Various modifications were then made to the duct burner flame holder to overcome the effect of the turbulence. A significant reduction in CO was observed when the flame holder was modified to make it less sensitive to the flow vector, either time averaged or instantaneous. Figure 5 shows a schematic diagram of the modified burner.

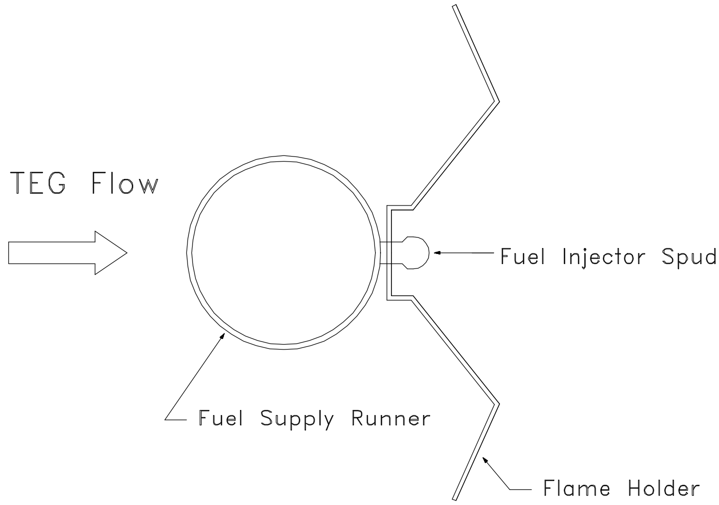


Figure 5 Schematic Cross-Section of Modified Duct Burner [John Zink LDRW]

Based on the improvements seen in the test facility the duct burners in the field were modified. Visual observations of the flames showed improved flame quality with a significant reduction in flame reversals. Figure 6 is a plot comparing the CO emissions of the original and modified designs.

(Figure not included)

Figure 6 Comparison of CO Emissions of Original and Modified Designs

This data shows a significant reduction in CO emissions and reduction in sensitivity to steam injection. NOx emissions were not adversely impacted by the modifications. In this case the resulting combustible emissions were well below the requirements of the application.

CONCLUSIONS

The modified duct burner design has provided significant performance improvements under adverse conditions. Combustible emissions were reduced without increasing NOx emissions. The design provides for a more uniform supply of TEG into the flame stabilization zone and this supply is less influenced by variations in TEG flow. The modified flame holder performs effectively over an extended range of TEG turbulence, velocity, composition and flow vector variation. The edges of the flame holders also provide for less turbulent and more controlled mixing of the bulk TEG flow into the active flame zone which reduces quenching. In most cases flame lengths are actually reduced compared with the previous design.

In subsequent applications this modified design has proven to be useful for low CO and VOC emission requirements in applications with one or more of the following:

flow maldistribution
high steam injection rates

short flame requirements
low TEG flow velocities.

Economic benefits derived from reduced CO emissions in existing units will depend on the system configuration and operating parameters. Reduced CO emissions may provide emission "bubble" trade-offs and longer catalyst life, if CO catalyst is used. More importantly lower CO emissions may allow increased electrical generation at peak operating points by allowing increased power augmentation steam as well as increased auxiliary duct burner firing.

Attachment VI - C

Duct Burners Presentations

Presentation No. 3:COEN Company, Inc.

(To be included on the final version of the full minutes)

DUCT BURNER PERFORMANCE

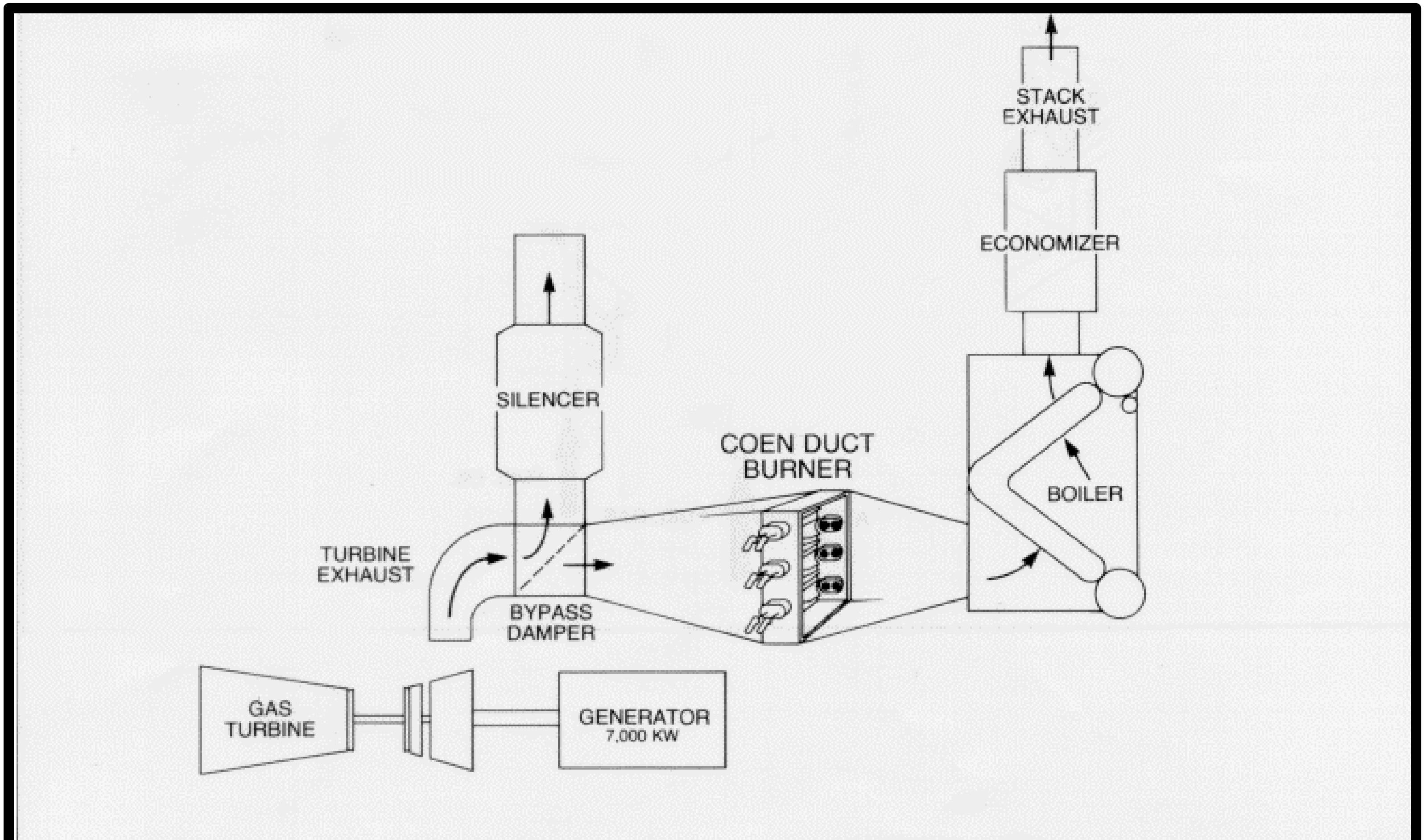
SCOTT A. DRENNAN

ICCR Meeting
Raleigh, North Carolina
September 18, 1997

OUTLINE

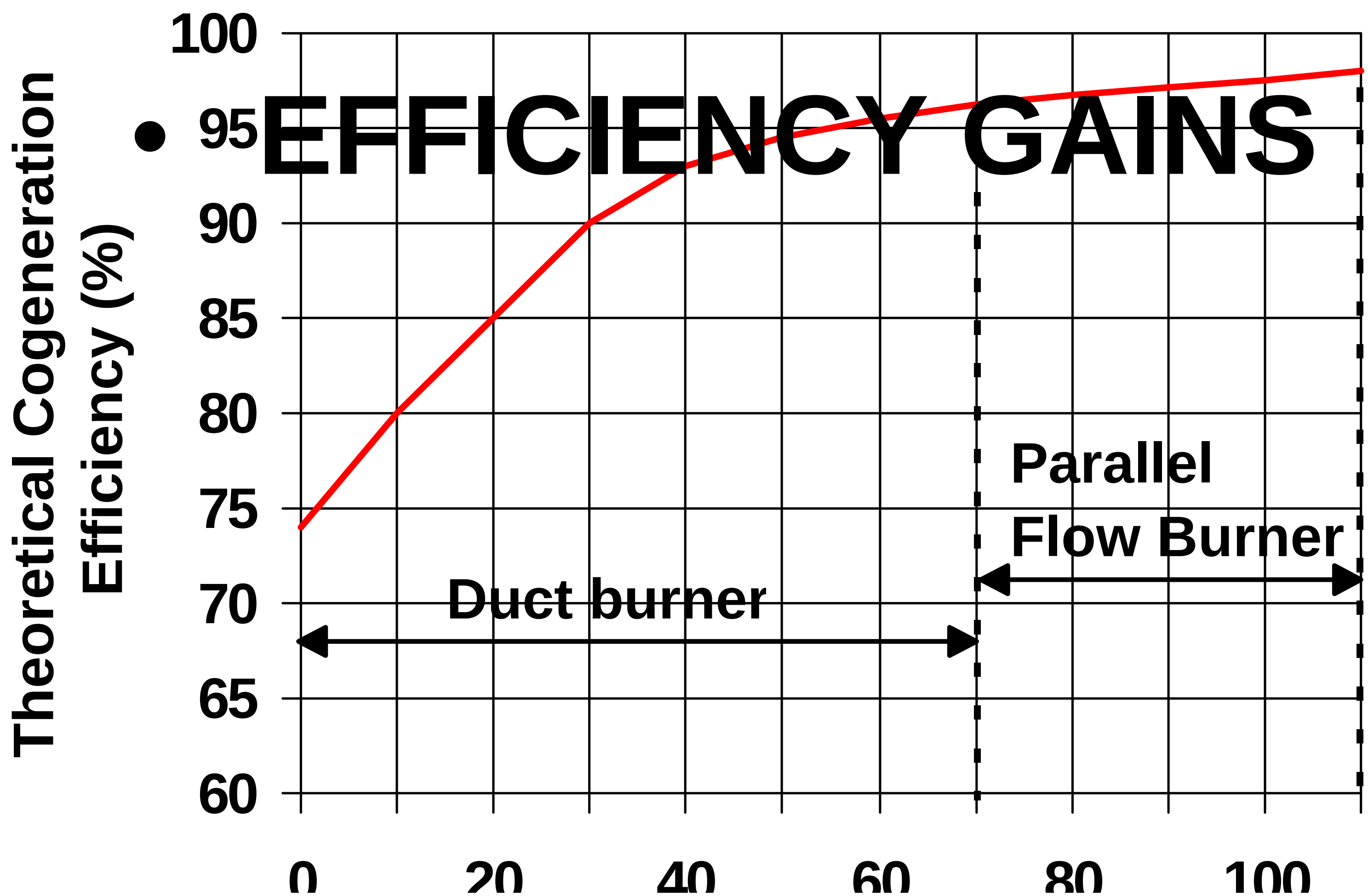
- DUCT BURNER TECHNOLOGY
- PERFORMANCE CONSIDERATIONS
- EMISSIONS CONSIDERATIONS
- DUCT BURNER BENEFITS
- SUMMARY
- DISCUSSION

COGENERATION SYSTEM

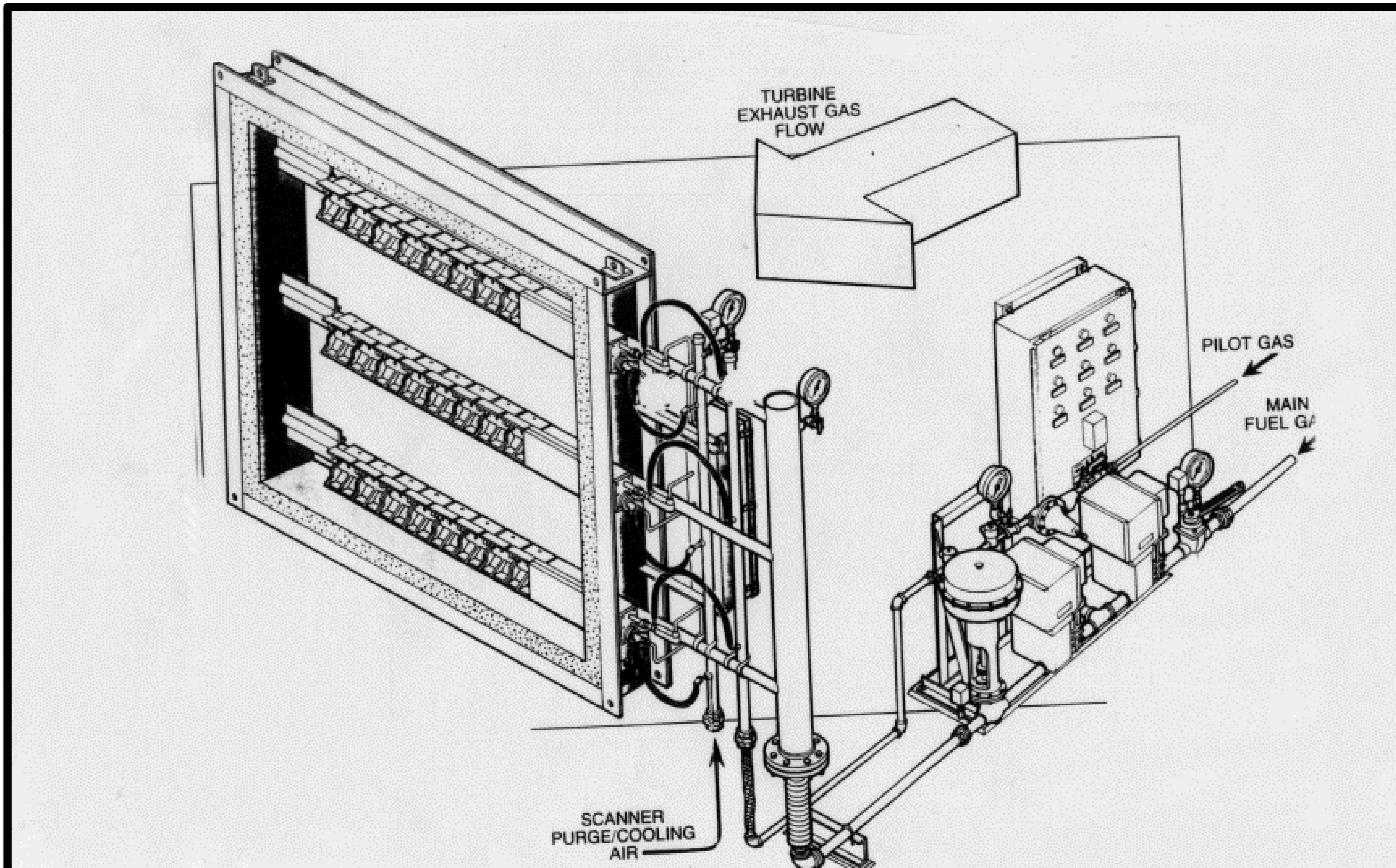


WHY SUPPLEMENTARY FIRING?

- **EFFICIENCY GAINS**



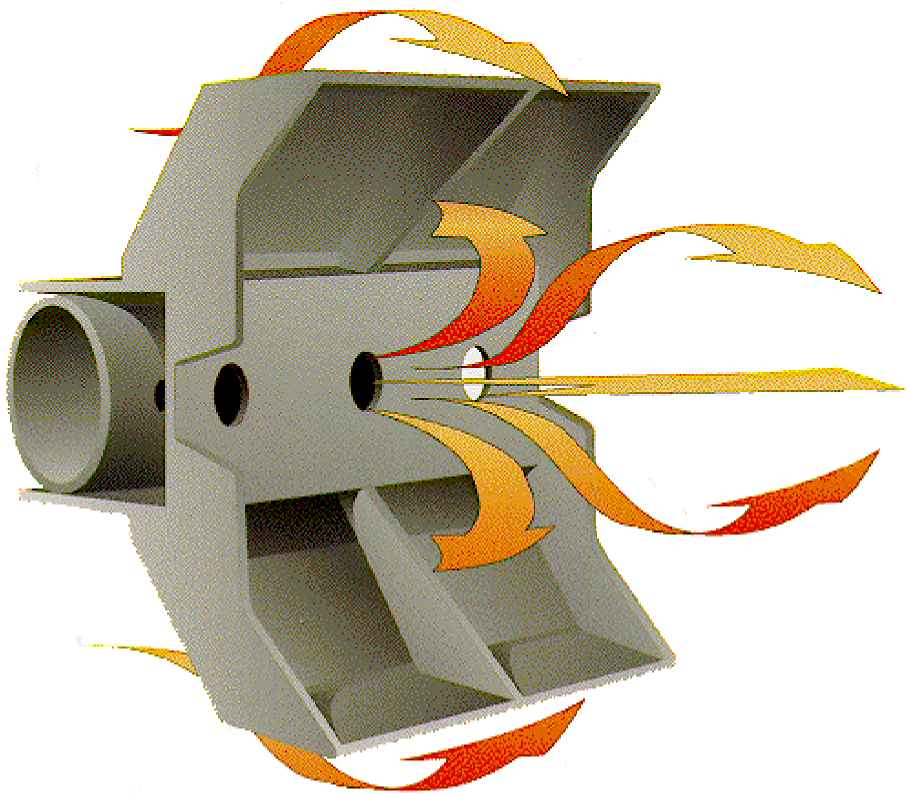
COEN DUCT BURNER



DUCT BURNER REQUIREMENTS

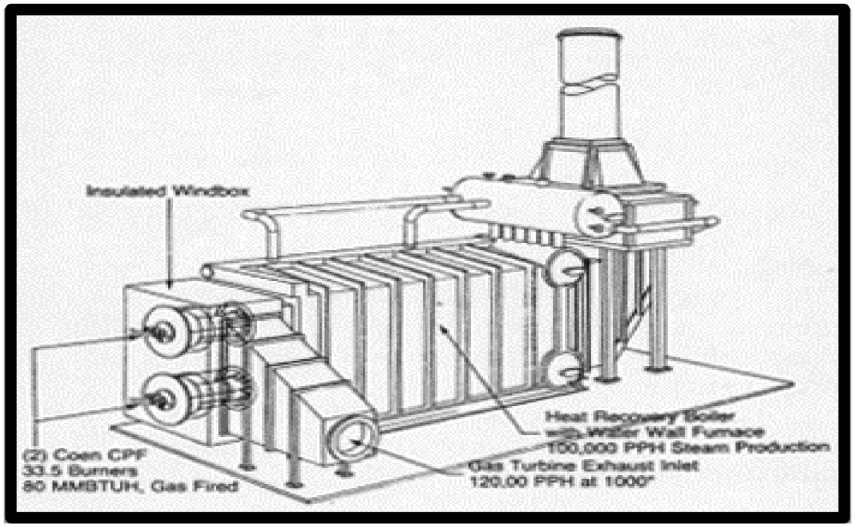
- LOW DRAFT LOSS ACROSS BURNERS
- UNIFORM HEAT DISTRIBUTION AT HRSG
- HIGH TURNDOWN RATIO
- AVOID AUGMENTING AIR REQUIREMENT
- RELIABLE OPERATION
- LOW EMISSIONS DESIGN
  - NO_x
  - CO
  - HYDROCARBONS

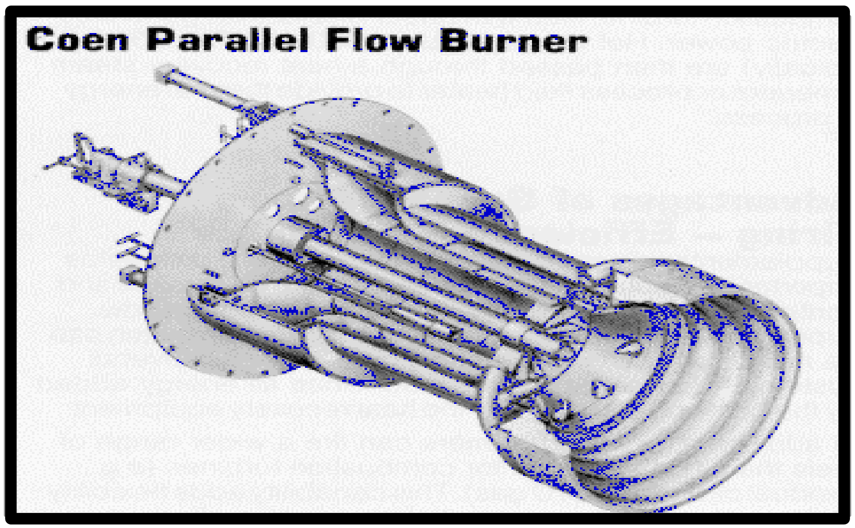
GAS FIRED DUCT BURNER



- **LOW CO DESIGN**
- **LOW HC DESIGN**
- **LOW DRAFT LOSS**
- **EVEN TEMPERATURE PROFILES**

COEN PARALLEL FLOW BURNER

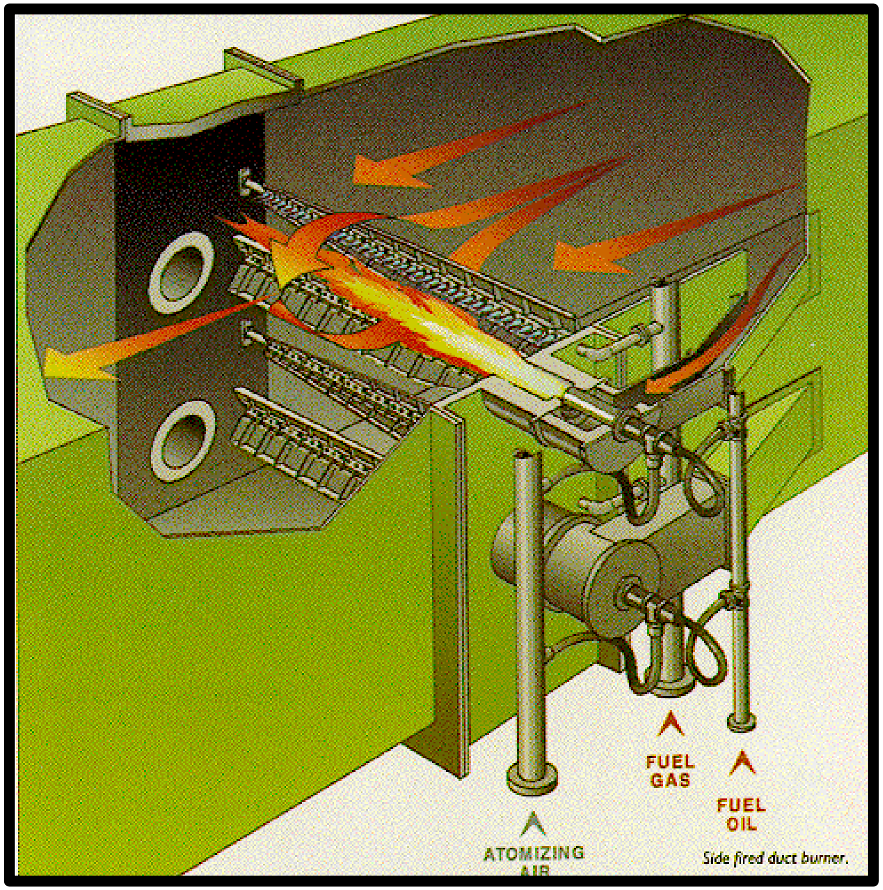




- **LOW NOx BURNER**
- **MAXIMUM SYSTEM EFFICIENCY**
- **LOW EXCESS AIR OPERATION**
- **FUEL FLEXIBILITY**

SIDE FIRED DUCT BURNER

- HEAVY LIQUID FUEL CAPABILITY
- ALTERNATIVE OR WASTE FUEL CAPABILITY
- FLAME STABILITY & FUEL/AIR MIXING CRITICAL
- POTENTIAL FOR HAP's



DUCT BURNER EMISSIONS

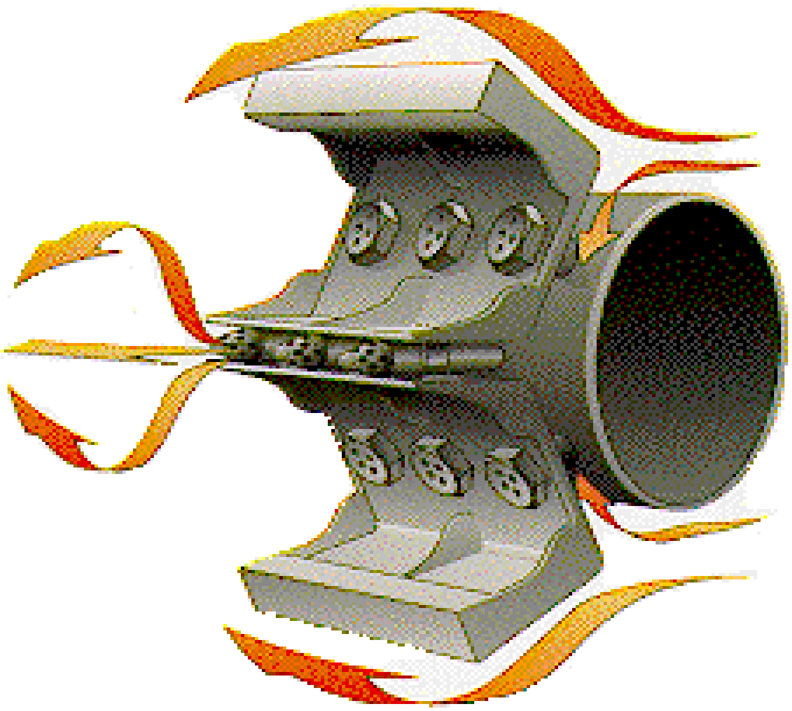
- NITROGEN OXIDES
- CARBON MONOXIDE
- UNBURNED HYDROCARBONS
  - UHC's
  - VOC's
  - ROG's
  - HAP's
- PARTICULATES

LOW EMISSIONS REQUIREMENTS

- **RELATIVELY UNIFORM TEG VELOCITY DISTRIBUTION**
- **MINIMIZE FLOW VARIATIONS**
- **ENHANCED FUEL / AIR MIXING**
- **PROVIDE ADEQUATE RESIDENCE TIME FOR COMBUSTION**

CUSTOM DUCT BURNERS

- **SPECIAL DESIGNS FOR COMPLEX FUEL AND EMISSIONS REQUIREMENTS**
- **AIR AUGMENTED DESIGNS**
- **LOW Btu GAS FIRING**
  - **LANDFILL GAS**
  - **BIOGAS**
  - **PRODUCER GAS**
  - **COAL GAS**



A low BTU gas duct burner for installation in coal gas fired facilities.

NOx CONSIDERATIONS

- THERMAL NOx
  - FORMED AT HIGH TEMPERATURES DUE TO ATMOSPHERIC NITROGEN DISASSOCATION

- FUEL NOx
  - NITROGEN CONTAINED IN THE FUEL COMBINES WITH OXYGEN ATOM TO FORM NO IN THE FLAME ZONE

CO AND HC CHARACTERISTICS

- **PRIMARY CAUSE OF CO PROBLEMS:**
  - **POOR TEG VELOCITY PROFILE**
  - **INSUFFICIENT FUEL / AIR MIXING**
  - **INSUFFICIENT RESIDENCE TIME**

- **TURBINE CO AND VOC's CAN BE GREATER THAN DUCT BURNER EMISSIONS**

- **DUCT BURNERS CAN BE USED TO INCINERATE TURBINE CO AND VOC's**

CO & HC EMISSIONS CHARACTERISTICS

- **FORMED AT LOW TEMPERATURE AND LOW OXYGEN ENVIRONMENTS**

- **DOWNSTREAM FIRING TEMPERATURE & DISTANCE**

- **CO AND HC EMISSIONS RATES VARY WIDELY OVER THE FIRING RATE OF THE DUCT BURNER**

- **EMISSIONS REPORT CAN HAVE DRAMATIC EFFECTS**
  - **lb/MBtu vs. ppm vs. lb/day**

HAZARDOUS AIR POLLUTANTS

- COEN HAS BEEN ASKED TO GUARANTEE ONLY ONE HAP (FORMALDEHYDE)
- COEN ROUTINELY GUARANTEES NO_x AND CO
- REQUESTS FOR VOC EMISSIONS GUARANTEES INCREASING
- SPECIFIC HC EMISSIONS DESTRUCTION APPLICATIONS

DUCT BURNER ADVANTAGES

- **DUCT BURNER CO OFTEN LOWER THAN INCOMING CO LEVELS**
  - **OXIDIZES TURBINE CO**
  - **OXIDIZES TURBINE HC**

- **DUCT BURNERS COULD BE USED IN ANY FIRED TURBINE COGEN SYSTEM TO PROVIDE THE MACT FOR HYDROCARBONS (VOC, ROG, HAP, etc.)**

TOOLS FOR EMISSIONS ESTIMATION

- IN-HOUSE EMPIRICAL DATA
- RESEARCH DATA
  - INTERNAL R & D
  - EXTERNAL RESEARCH
- COMPUTER KINETIC MODELING
- COMPUTATIONAL FLUID DYNAMIC MODELING
- CANNOT EXPERIMENTALLY TEST FOR A SINGLE HAP DRE FOR EACH SPECIAL APPLICATION

SUMMARY & DISCUSSION

- **COEN SUPPORTS RESPONSIBLE AND ACHIEVABLE EMISSIONS REGULATIONS OF HAP's**
- **CO AND NOx DOMINATE TODAY's EMISSIONS CONCERNS**
- **CURRENT HAP's REQUIREMENTS ARE NOT PROBLEMATIC**
- **ADJUSTMENTS IN TOXICITY OF HAP's CAN GREATLY AFFECT COMPLIANCE**
- **MORE FIELD DATA REQUIRED**